KNI-163-A

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	A. Matsumoto et al.
Serial No.:	Unknown
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Title:	"WE-TYPE COMPACTING METHOD FOR POWDER, PRODUCTION METHOD FOR SINTERED POWDER COMPACT, SINTERED POWDER COMPACT, AND APPARATUS USING SINTERED POWDER COMPACT"

PRELIMINARY AMENDMENT-A

Box PCT
Assistant Commissioner for Patents
Washington, DC 20231

Sir:

In connection with the subject new filing under 35 USC §371 (filed concurrently herewith), please amend the application as follows.

IN THE SPECIFICATION:

Please amend paragraphs [012], [019], [020], [022], [031], [046], [049], [051], [066], [071], [075], [079], [085], [087], [088] and [090], add new paragraph [095], and amend Tables 6-7 as shown on the attached sheets (including sheets with clean copies of the revised paragraphs and sheets showing the changes with underlining and brackets)

IN THE CLAIMS:

Please amend claims 1, 3-12, 15-18, 20, 22, 24, and 26-39 as shown on the attached sheets (including sheets with clean copies of the revised claims and sheets showing the changes with underlining and brackets).

Please cancel claim 40 without prejudice, and without dedication or abandonment of the

subject matter thereof. Also, please add new claims 41-44, which are shown on the attached sheets.

IN THE ABSTRACT:

Please amend the Abstract as shown on the attached sheet (including a sheet with a clean copy of the revised Abstract and a sheet showing the changes with brackets and underlining).

REMARKS

Upon entry of the present Preliminary Amendment-A the claims in the application are claims 1-39 and 41- 44, of which claims 1, 14, 18, 20, 32, 34 and 39 are independent.

The specification, claims and Abstract have been amended to overcome minor informalities therein, and to generally present more proper idiomatic English. Also, the claims are amended to eliminate all multiple dependencies therein, to cancel claim 40, and to present new claims 41-44, of which claims 41-42 are similar to original claims 2-3 except that they depend from claim 15, claim 43 presents a limitation deleted from claim 20, and claim 44 presents a limitation deleted from claim 39.

Applicant respectfully submits that all of the above amendments are fully supported by the original application, and that no new matter is added by the amendments.

Favorable consideration is respectfully requested.

Respectfully submitted,

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CERTIFICATE OF MAILING

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Joseph P. Carrier

[012] To cope with both the high speed and the high positioning accuracy, it is necessary to use a mobile body constructed from a material with a large specific rigidity ratio (Young's modulus / Specific gravity). Accordingly, in place of a conventional material of a metal system, the mobile body device adopting the movable section using a construction material made of ceramics has become available in recent years. For example, Japanese Unexamined Patent Publication No. HEI 4-347008 discloses that a fluid bearing made of ceramics is superior to a metal bearing in specific rigidity. A fluid bearing made of alumina is disclosed in Japanese Unexamined Patent Publication No. HEI 6-297421 as an embodiment thereof. Japanese Unexamined Patent Publication No. HEI 6-297421 also discloses examples of ceramic materials used in the fluid bearing, wherein silicon nitride and silicon carbide are mentioned, which will provide a ceramic sintered compact with a larger specific rigidity ratio than Alumina if they are completely densely sintered. Japanese Unexamined Patent Publication No. 2000-182945 also discloses members for a lithography device in which silicon carbide and boron carbide having a large specific rigidity ratio are used.

[019] When a compacting aid of organic high polymer is used in the wet-type powder compacting process and, for example, slip casting is adopted as a compacting method, the compacting aid soluble in a solvent often causes clogging in a mold. And the compacting aid soluble in the solvent sometimes causes its segregation in a compact in the process of drying the solvent from the compact and as a result, the compact after drying becomes heterogeneous. The heterogeneous compact remains heterogeneous even in the next sintering process and, as a result, a heterogeneous sintered compact is only available. And in compacting a non-plastic body, even if the compacting aid imparting plasticity is

added according to a conventional method, the plasticity is still inferior compared with plastic body such as a clay base body. Accordingly, there is a limit to the size and shape of the compact.

[020] Since these compacting aids must be burnt off in the next sintering process, the density of a sintered body decreases and as a result, satisfactory physical properties of the sintered body cannot be obtained. It is also difficult to uniformly disperse an ordinary sintering aid in a mixture of powder and solvent. As a result, the sintering aid heterogeneously existing in the compact results in heterogeneous physical properties of the sintered compact. Further, according to a method of promoting sintering by hot pressing under high temperature and high pressure, increase of manufacturing cost is inevitable. Basically, it is not possible to manufacture a large and complicated shaped product from the limits of the equipment by hot pressing.

[022] Further, when a sintered powder compact, in particular, a ceramic sintered powder compact [are] is applied to a movable section of a mobile body device having a highly accurate positioning function, if, for example, alumina is used, the specific rigidity ratio of alumina is about 80 ~ 95 GPa even if the alumina is sintered until its Young's modulus reaches close to the maximum value. The specific rigidity ratio in such a case is not enough to attain the superb throughput and positioning accuracy which are required, for example, in a lithography machine.

[031] According to the present invention, to solve the above problems, a wet-type compacting method for powder is provided, characterized in that a compact is produced from a mixture of a solvent and carbide powder coated with a high polymer organic

substance which is substantially insoluble in the solvent. A compact obtained by this compacting method is also provided. A production method for a sintered powder compact is provided, in which the compact obtained by the wet-type compacting method for powder is dried and then sintered. A production method for a sintered powder compact is provided, wherein a mixture including a ceramic powder, a solvent, and an aid as its main components is set as a starting material, and in compacting and sintering processes, the aid functions as a compacting aid for imparting plasticity and/or strength to a compact or its precursor in the compacting process, while the aid also exhibits an effect as a sintering aid for promoting sintering in the sintering process. A sintered powder compact obtained by this production method for a sintered powder compact is also provided. A production method for boron carbide sintered compact is provided, which comprises the steps of pouring slurry of a powder of which the main component is boron carbide of an average particle size of 0.3 μm ~ 1.4 μm, a compacting aid and a sintering aid dispersed together in a solvent into a porous mold, letting the porous mold absorb a part of the solvent to solidify the slurry, thereby forming a compact, and after drying the compact, atmospheric pressure sintering under a non-oxidizing atmosphere or HIP-treating after the atmospheric pressure sintering under a non-oxidizing atmosphere. A boron carbide sintered compact produced by the production method above is provided. A mobile body device having a positioning function is provided, in which the sintered compact is used in a part or all of a movable section of the mobile body device. A hydrostatic fluid bearing device is provided, in which a part or all of the movable section is made of material of a specific rigidity ratio of 100 GPa or more, and a part or all of the movable section has a hollow structure and/or rib structure. A protective member for absorbing shock from

collision with a missile including the sintered compact as its component is provided. A device having a protective member arranged obliquely to the estimated direction of collision of the missile in all or a part of its crust is provided, wherein the protective member has a curved structure for absorbing shock from collision with a missile and includes a ceramic sintered compact which has a curved structure as its component. A protective member having a curved section used in the device is provided.

[046] The compacting aid used in slip casting serves to improve the flow characteristics of the slurry and the dispersing characteristics of powder in the slurry and functions as a binder or plasticizer of the compact to improve compact strength. Desirable compacting aids other than those exemplified above as the high polymer organic substance include organic substances, for example, alginate such as sodium alginate, ammonium alginate, triethanolamine alginate; polycarboxylic acid ammonium, dibutyl phthalate, carboxylmethylcellulose, carboxylmethylcellulose sodium, carboxylmethycellulose ammonium, methylcellulose, methylcellulose sodium, hydroxylethylcellulose, hydroxylethylcellulose sodium, polyvinyl alcohol, polyethylene oxide, sodium polyacrylate, acrylic acid or its ammonium salt oligomer, various amines such as monoethylamine, pyridine, piperidine, tetramethylammonium hydroxide, dextrin, peptone, soluble starch, various polymers, various emulsions, and clays.

[049] Slip casting is the most desirable compacting method in the present invention as described above, but [a] other desirable methods for compacting a powder in the present invention [further] include[s] extrusion molding, wet-type press molding, thixotropic

molding, tape casting and the like. By using a mixture of powder and the solvent that exhibits plasticity, a method of compacting by utilizing that plasticity is also available. Compacting by utilizing plasticity means a method for compacting by applying force to a compact or a precursor of the compact such as kneaded body in the extrusion molding to utilize plastic deformation of the compact or the precursor of the compact in the compacting process. Extrusion molding is one example of compacting by utilizing plasticity. In these compacting methods, it is possible to suitably apply the present invention because plasticity is utilized in the compacting principle itself and strength of the compact is required during handling after compacting.

[051] As a field to which the present invention can be applied, a material that needs a sintering process following a compacting process is desirable and for example, a ceramic sintered compact obtained by compacting and sintering a ceramic powder is included therein. In this case, a method of producing a sintered powder compact characterized in that a mixture including a ceramic powder, a solvent and an aid as its main components is a starting material, wherein in compacting and sintering processes, the aid acts on a compact or the precursor thereof as a compacting aid in the compacting process, while in the sintering process, it also exhibits an effect as a sintering aid for promoting sintering, is also a new concept that the present invention provides. In this manner, the reason for using a common aid for the compacting and sintering aids used in each process with reference to the compacting and sintering methods of the ceramic powder is to ensure that sintering is not prevented. If the compacting aid is not related to sintering, it is necessary to remove the compacting aid during the sintering process by heating. This means that

density of the sintered compact is inevitably reduced for a portion [whereby] in which the compacting aid has been removed. The common aid can prevent such a situation.

[066] The most desirable means for producing a hollow structure and/or rib structure in the ceramic sintered compact is making such a structure by arranging molds of slip casting. Slip casting has two types: one is solid (double) casting in which molds are place[e]d on both sides of the compact to let them absorb a solvent, and the other is drain (single) casting in which a mold is placed on one side of the compact to let the excess slurry be discharged from the other side of the compact. To make the hollow structure, it is suitable to provide the mold arrangement whereby the slurry in the hollow section can be discharged. To make the rib structure, it is suitable to provide the mold arrangement whereby the solvent is absorbed by the molds that are placed on both sides of the rib section in the solid casting.

[071] It is also desirable to use a material with a high specific rigidity ratio even in this field in the same manner as in the mobile body device with a positioning function above. It has not yet been completely theoretically solved as to how the specific rigidity ratio of the protective member affects the absorption of shock from the collision with the missile, but it can be outlined as follows. For example, a case where a high-speed missile collides with a structural material provided with a backup layer of fiber reinforced plastics on the back surface of highly rigid ceramics is described here. When the missile collides with the surface of the ceramic material, a compressional wave which is a kind of elastic wave from the shock proceeds toward the backup layer at a speed proportional to the square

root of the specific rigidity ratio in the ceramic material and is propagated to a cone making the point of collision the apex thereof. The larger the speed, the wider area where the compressional wave reaches the backup layer and absorbs the shock, and as a result, the shock resistance improves. On the other hand, energy stored in the missile is not only absorbed by the protective member, but also consumed as the compressional wave causing the breakage of the missile itself. The larger the difference between the speed of the compressional wave propagated in the ceramic material and that in the missile, the larger the energy distributed to the compressional wave causing the breakage of the missile. In this case, the specific rigidity ratio of the ceramic material is larger than that of the missile. As a result, the larger specific rigidity ratio of the ceramics used as the component of the protective member is, the more its shock resistance improves.

[075] If the protective member according to the present invention is applied to a device of a structure such that the protective member is arranged obliquely to the predicted direction of collision with the missile, it can further increase the effect. This is the application of the principle whereby when the protective member is inclined at an angle of θ to the direction of collision with the missile, the apparent thickness thereof is multiplied by $1/\cos\theta$. When it is known that the missile will come from a specific direction, it is possible to design a tabular protective member with a large angle to that direction. However, when the in-coming direction cannot be specified without reservation, a protective member with a curved structure may be advantageous. In such a case, the ceramic sintered compact which is a component of the protective member may also be required to have a complicated curved shape to conform to the structure of the

protective member. In this case, a technique of the present invention can be suitably applied to such a ceramic sintered compact. Further, a complicated shaped protective member that could not be produced using conventional plate-shaped ceramics can be produced with the ceramic sintered compact according to the present invention. Still further, a structure that could be attained only by combining a plurality of protective members can be integrally produced <u>as a unitary member</u>. To produce such a complicated shaped protective member using ceramics, it is suitable to adopt slip casting in the compacting process.

[079] A mixed solution of an acetone solution of novolac type phenol resin (specific gravity: 1.18; manufactured by Showa Highpolymer Co., Ltd.) and a hexane solution of polycarbosilane was added to boron carbide powder (average particle size: 0.74 μm, specifi[f]c gravity: 2.5, manufactured by Electro Schmelzwerk Kempten GmbH), then the mixture was agitated. After sufficiently vaporizing an organic solvent, the mixture was shredded to provide boron carbide powder as a starting material. Compacting and sintering were performed using this powder in the same method and condition as in the first embodiment. The amounts of phenol resin and polycarbosilane added are shown by volume parts relative to the boron carbide powder.

[085] Using a slurry which had the same composition as a volume part of the phenol resin additive ratio (18.9%) in the first embodiment, a compact was made by means of a solid casting by a plaster slip casting and a drain casting by pressure slip casting of 1.8 [Mpa] <u>MPa</u>. In the plaster slip casting, hardening time was set as a half of estimated thickening time, while in the pressure slip casting, 3 minutes' hardening was performed at a pressure of 0.3 MPa after sludge was discharged. The compact had a diameter of 80 mm and a

thickness of 10 mm. The compact obtained in this manner was dried and then the relative density of the dried compact was measured by Archimedes' principle. Dry strength of the compact made by pressure slip casting was measured by a three-point bending strength test method according to JISR1601. Next, three-point bending strength according to a method of JISR1601, Young's modulus according to a resonance method and Young's modulus according to three-point bending by a method of JISR1602, and relative density and bulk specific gravity of the sintered compact according to Archimedes's principle were measured on samples sintered according to sintering patterns I and II of Table 9.

[087] 2.8 parts by volume of $TiB[2]_2$ and 100 parts by volume of boron carbide were mixed. A mixed powder of a boron carbide powder and a $TiB[2]_2$ powder obtained in the same method as in the third embodiment was prepared as a starting material. A slurry was prepared using the mixed powder coated with a phenol resin by the same additive rate and method as in the fifth embodiment, and a compact was made from the slurry and was sintered in the same manner as in the fifth embodiment. Then, physical properties of the compact were measured in the same manner as in the fifth embodiment. Measured results are shown in Table 4. A true specific gravity value used when a dried compact relative density and a sintered compact relative density were calculated was a value calculated from each specific gravity of the boron carbide powder and the $TiB[2]_2$ powder according to their mixed ratio.

[088] A compact was prepared using a slurry with the same composition as in the fifth embodiment and the same means and method employed in the pressure slip casting of the fifth embodiment. Two kinds of compacts of 80 mm diameter and deposition thickness of 10 mm and 30 mm were prepared and dried. Their dried compact relative density was

measured according to the principle of Archimedes. After measurement, the two compacts with thickness of 10 mm and 30 mm were sintered according to sintering patterns III, IV of Table 9. Three-point bending strength according to a technique of JISR1601, Young's modulus by three-point bending according to a technique of JISR1602, sintered compact relative density and bulk specific gravity according to Archimedes' principle were measured on sintered compacts obtained in the manner stated above. Each sintered compact was divided into two: the upper (slurry surface side) portion and the lower (water absorbing surface side) portion and three-point bending strength, Young's modulus, sintered compact relative density and bulk specific gravity were measured on each portion[s]. Measured results are shown in Table 5.

[090] Using a slurry with the same composition as in the fifth embodiment and according to pressure slip casting of 1.5 MPa, [Large] large compacts were prepared by means of a solid casting and drain casting. Shapes of the compacts were a rib structure as shown in Fig. 1 and a curved structure as shown in Fig. 2 in the case of the solid casting, and a hollow structure as shown in Fig. 3 in the case of drain casting. In the case of solid casting, 130% of the estimated deposition time was provided as pressing time, while in the case of drain casting, after deposition was attained, the slurry was discharged and the deposited slurry was hardened for five minutes at a pressure of 0.4 MPa. When the compact was demolded, a back pressure of 0.2 MPa was applied to the mold. As a result, the compact could be demolded by water screen between the compact and the mold without any deformation or damage.

[095] Although there have been described in detail what are the preferred embodiments of the present invention, it will be understood by persons skilled in the art that variations and modifications may be made thereto without departing from the gist, sprit or essence of the invention. The scope of the invention is indicated by the appended claims.

6.

(Table 6)

	Sintering pattern	Bulk specific gravity	Sintered compact relative density (%)	Young's modulus (GPa)	Specific rigidity ratio (GPa)	Bending strength (N/mm^2)
Pressure slip casting	IV	2.17	86.6	230	106	81

(Table 7)

	Sintering pattern	Bulk specific gravity	Sintered compact relative density (%)	Young's modulus (GPa)	Specific rigidity ratio (GPa)	Bending strength (N/mm^2)
8th embodiment	IV	2.48	99.9	405	163	631

1. (amended) A wet-type compacting method for powder [characterized in that a compact is produced from] comprising the steps of: forming a mixture of a solvent and carbide powder coated with high polymer organic substance that is substantially insoluble in the solvent; and producing a compact from said mixture.

3. (amended) A wet-type compacting method for powder according to claim 1 [or claim 2], wherein a volume fraction of the powder and the high polymer organic substance in the mixture is 1 - 40 parts by volume of the high polymer organic substance to 100 parts by volume of the powder.

4. (amended) A wet-type compacting method for powder according to claim[s] 1 [through 3], wherein [a slurry that is] the mixture is in the form of a slurry, and said producing step involves pouring the slurry [poured] into a porous mold to let the mold absorb a part of the solvent, thereby producing the compact.

5. (amended) A wet-type compacting method for powder according to claim[s] 1 [through 3], wherein [a compacting method of] said producing [the compact from the mixture is selected from a group consisting] step involves one of extrusion molding, wet-type press molding, thixotropic molding and tape casting.

6. (amended) A wet-type compacting method for powder according to claim[s] 1 [through 5], wherein the mixture exhibits plasticity and [the compact is produced by making] said producing step involves use of the plasticity.

7. (amended) A [production method for a sintered powder compact characterized in that the compact obtained by the wet-type compacting] method [for powder] according to claim[s] 1 [through 6 is dried and sintered], further comprising the steps of: drying the produced compact; and sintering the dried compact.

8. (amended) A [production] method [for a sintered powder compact] according to claim 7, wherein the high polymer organic substance exhibits a function as a sintering aid of the powder when sintered.

9. (amended) A [production] method [for a sintered powder compact] according to claim 8, wherein [by performing] all or a part of [a] said sintering [process] step is performed in a non-oxidizing atmosphere, such that the high polymer organic substance is reformed to a substance which contains carbon from the high polymer organic substance as its main component, and the substance containing the carbon as its main component exhibits a function as a sintering aid of the powder.

10. (amended) A [production] method [for a sintered powder compact] according to claim[s] 7 [through 9], wherein the carbide powder is a non-plastic inorganic powder.

11. (amended) A [production] method [for a sintered powder compact] according to claim 10, wherein the non-plastic inorganic powder is a carbide ceramic powder.

12. (amended) A sintered powder compact obtained by the [production] method [for a sintered powder compact] according to claim[s] 7 [through 11].

15. (amended) A mixture according to claim 14, wherein the [mixture is used in the wet-type compacting method for powder according to claims 1 through 6 and/or the production method for a sintered powder compact according to claims 7 through 11] powder comprises carbide powder.

16. (amended) A powder coated with a high polymer organic substance for use in the mixture according to claim 14 [or claim 15].

17. (amended) A compact obtained by the wet-type compacting method of powder according to claim[s] 1 [through 6].

18. (amended) A production method for a sintered powder compact [characterized in that] comprising the steps of: preparing a starting mixture containing a ceramic powder, a solvent and an aid as [the] main components thereof [is a starting material, wherein in] ; compacting the starting mixture; and sintering [processes,] the compacted mixture, wherein the aid functions as a compacting aid for providing at least one of plasticity and[/or] strength to a compact or its precursor in the compacting [process] step, while, in the sintering [process] step, the aid exhibits an effect as a sintering aid for promoting sintering.

20. (amended) A production method for a boron carbide sintered compact comprising the steps of:

[D]dispersing a powder of which the main component is boron carbide of an average particle size of 0.3 μm ~ 1.4 μm together with a compacting aid and a sintering aid in a solvent to form a slurry;

pouring the slurry into a porous mold;

letting the porous mold absorb a part of the solvent to solidify the slurry, thereby making a compact;

drying the compact; and

sintering the compact under atmospheric pressure and a non-oxidizing atmosphere [or performing HIP treatment after the atmospheric pressure sintering under a non-oxidizing atmosphere].

22. (amended) A mobile body device with a positioning function, wherein part or all of a movable section of the mobile body device [is constructed with the] comprises a sintered

powder compact produced according to [claim 12 or claim 13 as a component] the method of claim 7.

24. (amended) A mobile body device according to claim 22 [or claim 23], wherein the mobile body device is a hydrostatic fluid bearing device.

26. (amended) A mobile body device according to claim 25, wherein the tabular object is one of a semiconductor wafer [or] and a liquid crystal panel.

27. (amended) A mobile body device according to claim[s] 22 [through 26], wherein said part or all of the movable section [constructed with the sintered powder compact according to claim 12 or claim 13 as a component is designed to have] has at least one of a hollow structure and[/or] a rib structure.

28. (amended) A mobile body device according to claim 27, wherein said at least one of the hollow structure and[/or] the rib structure [are] is formed by arranging molds during slip casting.

29. (amended) A mobile body device according to claim 27, wherein said at least one of the hollow structure and[/or] the rib structure [are] is formed by joining [the] a plurality of said sintered powder compacts.

30. (amended) A mobile body device according to claim 27, wherein said at least one of the hollow structure and[/or] the rib structure [are] is formed by soldering the sintered compact.

31. (amended) A mobile body device according to claim 27, wherein said at least one of the hollow structure and[/or] the rib structure [are] is formed by processing the compact before sintering.

32. (amended) A hydrostatic fluid bearing device [characterized in that], wherein part or

all of a movable section of the device is made of material [of] having a specific rigidity ratio of 100 GPa or more, and part or all of the movable section [is designed to have] has at least one of a hollow structure and[/or] a rib structure.

33. (amended) A protective member for absorbing shock from collision with a missile [(a flying object) which includes the] comprising a sintered powder compact produced according to [claim 12 or claim 13 as a component] the method of claim 7.

34. (amended) A protective member for absorbing shock from collision with a missile [(a flying object) which includes as a component] comprising a sintered powder compact made by slip casting and sintering of a ceramic powder.

35. (amended) A protective member for absorbing shock from collision with a missile [(a flying object)] according to claim 33 [or claim 34], wherein the protective member further includes a backup material [for] provided together with the sintered powder compact for absorbing shock from collision with the missile [as a component].

36. (amended) A protective member for absorbing shock from collision with a missile [(a flying object)] according to claim[s] 33 [through 35], [wherein] further comprising at least one other material provided on opposite sides of the sintered powder compact [is sandwiched by other material] in a sandwiched structure.

37. (amended) A device equipped with the protective member for absorbing shock from collision with a missile according to claim[s] 33 [through 36] on all or a part of [its] a crust of the device.

38. (amended) A device according to claim 37, wherein all or part of the crust equipped with the protective member for absorbing shock from collision with a missile [(a flying object)] is obliquely provided to [the] an estimated direction of collision with the missile.

39. (amended) A device equipped with a protective member with a curved structure for absorbing shock from collision with a missile [(a flying object) including as a component], comprising a ceramic sintered compact with a curved structure provided on all or part of [its] a crust[, wherein the protective member is provided obliquely to the estimated direction of collision with the missile] of the device.

41. (new) A mixture according to claim 15, wherein a main component of the solvent is water.

42. (new) A mixture according to claim 15, wherein a volume fraction of the powder and the high polymer organic substance in the mixture is 1 - 40 parts by volume of the high polymer organic substance to 100 parts by volume of the powder.

43. (new) A production method according to claim 20, comprising a further step of performing HIP treatment on the sintered compact.

44. (new) A device according to claim 39, wherein the protective member is provided obliquely to an estimated direction of collision with the missile.

Abstract

A[ccording to the present invention, there provided a] wet-type compacting method of a ceramic powder using a solvent, wherein the ceramic powder is coated with a high polymer organic substance which is substantially insoluble in the solvent so that homogeneity of a compact is kept, while generating no problem during each process and excellent plasticity and /or strength are [applied to] exhibited by the compact, and if a sintering process follows a compacting process, sintering characteristics are improved.

[012] To cope with both the high speed and the high positioning accuracy, it is necessary to use a mobile body constructed from a material with a large specific rigidity ratio (Young's modulus / Specific gravity). Accordingly, in place of a conventional material of a metal system, the mobile body device adopting the movable section using a construction material made of ceramics has become available in recent years. For example, Japanese Unexamined Patent Publication No. HEI 4-347008 discloses that a fluid bearing made of ceramics is superior to a metal bearing in specific rigidity. A fluid bearing made of alumina is disclosed in Japanese Unexamined Patent Publication No. HEI 6-297421 as an embodiment thereof. Japanese Unexamined Patent Publication No. HEI 6-297421 also discloses examples of ceramic materials used in the fluid bearing, wherein silicon nitride and silicon carbide are mentioned, which will provide a ceramic sintered compact with a larger specific rigidity ratio than Alumina if they are completely densely sintered. Japanese Unexamined Patent Publication No. 2000-182945 also discloses members for a lithography device in which silicon carbide and boron carbide having a large specific rigidity ratio are used.

[019] When a compacting aid of organic high polymer is used in the wet-type powder compacting process and, for example, slip casting is adopted as a compacting method, the compacting aid soluble in a solvent often causes clogging in a mold. And the compacting aid soluble in the solvent sometimes causes its segregation in a compact in the process of drying the solvent from the compact and as a result, the compact after drying becomes heterogeneous. The heterogeneous compact remains heterogeneous even in the next sintering process and, as a result, a heterogeneous sintered compact is only available. And in compacting a non-plastic body, even if the compacting aid imparting plasticity is

added according to a conventional method, the plasticity is still inferior compared with plastic body such as a clay base body. Accordingly, there is a limit to the size and shape of the compact.

[020] Since these compacting aids must be burnt off in the next sintering process, the density of a sintered body decreases and as a result, satisfactory physical properties of the sintered body cannot be obtained. It is also difficult to uniformly disperse an ordinary sintering aid in a mixture of powder and solvent. As a result, the sintering aid heterogeneously existing in the compact results in heterogeneous physical properties of the sintered compact. Further, according to a method of promoting sintering by hot pressing under high temperature and high pressure, increase of manufacturing cost is inevitable. Basically, it is not possible to manufacture a large and complicated shaped product from the limits of the equipment by hot pressing.

[022] Further, when a sintered powder compact, in particular, a ceramic sintered powder compact is applied to a movable section of a mobile body device having a highly accurate positioning function, if, for example, alumina is used, the specific rigidity ratio of alumina is about 80 ~ 95 GPa even if the alumina is sintered until its Young's modulus reaches close to the maximum value. The specific rigidity ratio in such a case is not enough to attain the superb throughput and positioning accuracy which are required, for example, in a lithography machine.

[031] According to the present invention, to solve the above problems, a wet-type compacting method for powder is provided, characterized in that a compact is produced from a mixture of a solvent and carbide powder coated with a high polymer organic

substance which is substantially insoluble in the solvent. A compact obtained by this compacting method is also provided. A production method for a sintered powder compact is provided, in which the compact obtained by the wet-type compacting method for powder is dried and then sintered. A production method for a sintered powder compact is provided, wherein a mixture including a ceramic powder, a solvent, and an aid as its main components is set as a starting material, and in compacting and sintering processes, the aid functions as a compacting aid for imparting plasticity and/or strength to a compact or its precursor in the compacting process, while the aid also exhibits an effect as a sintering aid for promoting sintering in the sintering process. A sintered powder compact obtained by this production method for a sintered powder compact is also provided. A production method for boron carbide sintered compact is provided, which comprises the steps of pouring slurry of a powder of which the main component is boron carbide of an average particle size of 0.3 μm ~ 1.4 μm, a compacting aid and a sintering aid dispersed together in a solvent into a porous mold, letting the porous mold absorb a part of the solvent to solidify the slurry, thereby forming a compact, and after drying the compact, atmospheric pressure sintering under a non-oxidizing atmosphere or HIP-treating after the atmospheric pressure sintering under a non-oxidizing atmosphere. A boron carbide sintered compact produced by the production method above is provided. A mobile body device having a positioning function is provided, in which the sintered compact is used in a part or all of a movable section of the mobile body device. A hydrostatic fluid bearing device is provided, in which a part or all of the movable section is made of material of a specific rigidity ratio of 100 GPa or more, and a part or all of the movable section has a hollow structure and/or rib structure. A protective member for absorbing shock from

collision with a missile including the sintered compact as its component is provided. A device having a protective member arranged obliquely to the estimated direction of collision of the missile in all or a part of its crust is provided, wherein the protective member has a curved structure for absorbing shock from collision with a missile and includes a ceramic sintered compact which has a curved structure as its component. A protective member having a curved section used in the device is provided.

[046] The compacting aid used in slip casting serves to improve the flow characteristics of the slurry and the dispersing characteristics of powder in the slurry and functions as a binder or plasticizer of the compact to improve compact strength. Desirable compacting aids other than those exemplified above as the high polymer organic substance include organic substances, for example, alginate such as sodium alginate, ammonium alginate, triethanolamine alginate; polycarboxylic acid ammonium, dibutyl phthalate, carboxylmethylcellulose, carboxylmethylcellulose sodium, carboxylmethycellulose ammonium, methylcellulose, methylcellulose sodium, hydroxylethylcellulose, hydroxylethylcellulose sodium, polyvinyl alcohol, polyethylene oxide, sodium polyacrylate, acrylic acid or its ammonium salt oligomer, various amines such as monoethylamine, pyridine, piperidine, tetramethylammonium hydroxide, dextrin, peptone, soluble starch, various polymers, various emulsions, and clays.

[049] Slip casting is the most desirable compacting method in the present invention as described above, but other desirable methods for compacting a powder in the present invention include extrusion molding, wet-type press molding, thixotropic molding, tape

casting and the like. By using a mixture of powder and the solvent that exhibits plasticity, a method of compacting by utilizing that plasticity is also available. Compacting by utilizing plasticity means a method for compacting by applying force to a compact or a precursor of the compact such as kneaded body in the extrusion molding to utilize plastic deformation of the compact or the precursor of the compact in the compacting process. Extrusion molding is one example of compacting by utilizing plasticity. In these compacting methods, it is possible to suitably apply the present invention because plasticity is utilized in the compacting principle itself and strength of the compact is required during handling after compacting.

[051] As a field to which the present invention can be applied, a material that needs a sintering process following a compacting process is desirable and for example, a ceramic sintered compact obtained by compacting and sintering a ceramic powder is included therein. In this case, a method of producing a sintered powder compact characterized in that a mixture including a ceramic powder, a solvent and an aid as its main components is a starting material, wherein in compacting and sintering processes, the aid acts on a compact or the precursor thereof as a compacting aid in the compacting process, while in the sintering process, it also exhibits an effect as a sintering aid for promoting sintering, is also a new concept that the present invention provides. In this manner, the reason for using a common aid for the compacting and sintering aids used in each process with reference to the compacting and sintering methods of the ceramic powder is to ensure that sintering is not prevented. If the compacting aid is not related to sintering, it is necessary to remove the compacting aid during the sintering process by heating. This means that

density of the sintered compact is inevitably reduced for a portion in which the compacting aid has been removed. The common aid can prevent such a situation.

[066] The most desirable means for producing a hollow structure and/or rib structure in the ceramic sintered compact is making such a structure by arranging molds of slip casting. Slip casting has two types: one is solid (double) casting in which molds are placed on both sides of the compact to let them absorb a solvent, and the other is drain (single) casting in which a mold is placed on one side of the compact to let the excess slurry be discharged from the other side of the compact. To make the hollow structure, it is suitable to provide the mold arrangement whereby the slurry in the hollow section can be discharged. To make the rib structure, it is suitable to provide the mold arrangement whereby the solvent is absorbed by the molds that are placed on both sides of the rib section in the solid casting.

[071] It is also desirable to use a material with a high specific rigidity ratio even in this field in the same manner as in the mobile body device with a positioning function above. It has not yet been completely theoretically solved as to how the specific rigidity ratio of the protective member affects the absorption of shock from the collision with the missile, but it can be outlined as follows. For example, a case where a high-speed missile collides with a structural material provided with a backup layer of fiber reinforced plastics on the back surface of highly rigid ceramics is described here. When the missile collides with the surface of the ceramic material, a compressional wave which is a kind of elastic wave from the shock proceeds toward the backup layer at a speed proportional to the square

root of the specific rigidity ratio in the ceramic material and is propagated to a cone making the point of collision the apex thereof. The larger the speed, the wider area where the compressional wave reaches the backup layer and absorbs the shock, and as a result, the shock resistance improves. On the other hand, energy stored in the missile is not only absorbed by the protective member, but also consumed as the compressional wave causing the breakage of the missile itself. The larger the difference between the speed of the compressional wave propagated in the ceramic material and that in the missile, the larger the energy distributed to the compressional wave causing the breakage of the missile. In this case, the specific rigidity ratio of the ceramic material is larger than that of the missile. As a result, the larger specific rigidity ratio of the ceramics used as the component of the protective member is, the more its shock resistance improves.

[075] If the protective member according to the present invention is applied to a device of a structure such that the protective member is arranged obliquely to the predicted direction of collision with the missile, it can further increase the effect. This is the application of the principle whereby when the protective member is inclined at an angle of θ to the direction of collision with the missile, the apparent thickness thereof is multiplied by $1/\cos\theta$. When it is known that the missile will come from a specific direction, it is possible to design a tabular protective member with a large angle to that direction. However, when the in-coming direction cannot be specified without reservation, a protective member with a curved structure may be advantageous. In such a case, the ceramic sintered compact which is a component of the protective member may also be required to have a complicated curved shape to conform to the structure of the

protective member. In this case, a technique of the present invention can be suitably applied to such a ceramic sintered compact. Further, a complicated shaped protective member that could not be produced using conventional plate-shaped ceramics can be produced with the ceramic sintered compact according to the present invention. Still further, a structure that could be attained only by combining a plurality of protective members can be integrally produced as a unitary member. To produce such a complicated shaped protective member using ceramics, it is suitable to adopt slip casting in the compacting process.

[079] A mixed solution of an acetone solution of novolac type phenol resin (specific gravity: 1.18; manufactured by Showa Highpolymer Co., Ltd.) and a hexane solution of polycarbosilane was added to boron carbide powder (average particle size: 0.74 μm, specific gravity: 2.5, manufactured by Electro Schmelzwerk Kempten GmbH), then the mixture was agitated. After sufficiently vaporizing an organic solvent, the mixture was shredded to provide boron carbide powder as a starting material. Compacting and sintering were performed using this powder in the same method and condition as in the first embodiment. The amounts of phenol resin and polycarbosilane added are shown by volume parts relative to the boron carbide powder.

[085] Using a slurry which had the same composition as a volume part of the phenol resin_additive ratio (18.9%) in the first embodiment, a compact was made by means of a solid casting by a plaster slip casting and a drain casting by pressure slip casting of 1.8 MPa. In the plaster slip casting, hardening time was set as a half of estimated thickening time, while in the pressure slip casting, 3 minutes' hardening was performed at a pressure

of 0.3 MPa after sludge was discharged. The compact had a diameter of 80 mm and a thickness of 10 mm. The compact obtained in this manner was dried and then the relative density of the dried compact was measured by Archimedes' principle. Dry strength of the compact made by pressure slip casting was measured by a three-point bending strength test method according to JISR1601. Next, three-point bending strength according to a method of JISR1601, Young's modulus according to a resonance method and Young's modulus according to three-point bending by a method of JISR1602, and relative density and bulk specific gravity of the sintered compact according to Archimedes's principle were measured on samples sintered according to sintering patterns I and II of Table 9.

[087] 2.8 parts by volume of TiB_2 and 100 parts by volume of boron carbide were mixed. A mixed powder of a boron carbide powder and a TiB_2 powder obtained in the same method as in the third embodiment was prepared as a starting material. A slurry was prepared using the mixed powder coated with a phenol resin by the same additive rate and method as in the fifth embodiment, and a compact was made from the slurry and was sintered in the same manner as in the fifth embodiment. Then, physical properties of the compact were measured in the same manner as in the fifth embodiment. Measured results are shown in Table 4. A true specific gravity value used when a dried compact relative density and a sintered compact relative density were calculated was a value calculated from each specific gravity of the boron carbide powder and the TiB_2 powder according to their mixed ratio.

[088] A compact was prepared using a slurry with the same composition as in the fifth embodiment and the same means and method employed in the pressure slip casting of the fifth embodiment. Two kinds of compacts of 80 mm diameter and deposition thickness of 10 mm and 30 mm were prepared and dried. Their dried compact relative density was measured according to the principle of Archimedes. After measurement, the two compacts with thickness of 10 mm and 30 mm were sintered according to sintering patterns III, IV of Table 9. Three-point bending strength according to a technique of JISR1601, Young's modulus by three-point bending according to a technique of JISR1602, sintered compact relative density and bulk specific gravity according to Archimedes' principle were measured on sintered compacts obtained in the manner stated above. Each sintered compact was divided into two: the upper (slurry surface side) portion and the lower (water absorbing surface side) portion and three-point bending strength, Young's modulus, sintered compact relative density and bulk specific gravity were measured on each portion. Measured results are shown in Table 5.

[090] Using a slurry with the same composition as in the fifth embodiment and according to pressure slip casting of 1.5 MPa, large compacts were prepared by means of a solid casting and drain casting. Shapes of the compacts were a rib structure as shown in Fig. 1 and a curved structure as shown in Fig. 2 in the case of the solid casting, and a hollow structure as shown in Fig. 3 in the case of drain casting. In the case of solid casting, 130% of the estimated deposition time was provided as pressing time, while in the case of drain casting, after deposition was attained, the slurry was discharged and the deposited slurry was hardened for five minutes at a pressure of 0.4 MPa. When the compact was

demolded, a back pressure of 0.2 MPa was applied to the mold. As a result, the compact could be demolded by water screen between the compact and the mold without any deformation or damage.

[095] Although there have been described in detail what are the preferred embodiments of the present invention, it will be understood by persons skilled in the art that variations and modifications may be made thereto without departing from the gist, sprit or essence of the invention. The scope of the invention is indicated by the appended claims.

6.

(Table 6)

	Sintering pattern	Bulk specific gravity	Sintered compact relative density (%)	Young's modulus (GPa)	Specific rigidity ratio (GPa)	Bending strength (N/mm^2)
Pressure slip casting	IV	2.17	86.6	230	106	81

(Table 7)

	Sintering pattern	Bulk specific gravity	Sintered compact relative density (%)	Young's modulus (GPa)	Specific rigidity ratio (GPa)	Bending strength (N/mm^2)
8th embodiment	IV	2.48	99.9	405	163	631

1. A wet-type compacting method for powder comprising the steps of: forming a mixture of a solvent and carbide powder coated with high polymer organic substance that is substantially insoluble in the solvent; and producing a compact from said mixture.

3. A wet-type compacting method for powder according to claim 1, wherein a volume fraction of the powder and the high polymer organic substance in the mixture is 1 - 40 parts by volume of the high polymer organic substance to 100 parts by volume of the powder.

4. A wet-type compacting method for powder according to claim 1, wherein the mixture is in the form of a slurry, and said producing step involves pouring the slurry into a porous mold to let the mold absorb a part of the solvent, thereby producing the compact.

5. A wet-type compacting method for powder according to claim 1, wherein said producing step involves one of extrusion molding, wet-type press molding, thixotropic molding and tape casting.

6. A wet-type compacting method for powder according to claim 1, wherein the mixture exhibits plasticity and said producing step involves use of the plasticity.

7. A method according to claim 1, further comprising the steps of: drying the produced compact; and sintering the dried compact.

8. A method according to claim 7, wherein the high polymer organic substance exhibits a function as a sintering aid of the powder when sintered.

9. A method according to claim 8, wherein all or a part of said sintering step is performed in a non-oxidizing atmosphere, such that the high polymer organic substance is reformed to a substance which contains carbon from the high polymer organic

substance as its main component, and the substance containing the carbon as its main component exhibits a function as a sintering aid of the powder.

10. A method according to claim 7, wherein the carbide powder is a non-plastic inorganic powder.

11. A method according to claim 10, wherein the non-plastic inorganic powder is a carbide ceramic powder.

12. A sintered powder compact obtained by the method according to claim 7.

15. A mixture according to claim 14, wherein the powder comprises carbide powder.

16. A powder coated with a high polymer organic substance for use in the mixture according to claim 14.

17. A compact obtained by the wet-type compacting method of powder according to claim 1.

18. A production method for a sintered powder compact comprising the steps of: preparing a starting mixture containing a ceramic powder, a solvent and an aid as main components thereof; compacting the starting mixture; and sintering the compacted mixture, wherein the aid functions as a compacting aid for providing at least one of plasticity and strength to a compact or its precursor in the compacting step, while, in the sintering step, the aid exhibits an effect as a sintering aid for promoting sintering.

20. A production method for a boron carbide sintered compact comprising the steps of:

dispersing a powder of which the main component is boron carbide of an average particle size of 0.3 μm ~ 1.4 μm together with a compacting aid and a sintering aid in a solvent to form a slurry;

pouring the slurry into a porous mold;

letting the porous mold absorb a part of the solvent to solidify the slurry, thereby making a compact;

drying the compact; and

sintering the compact under atmospheric pressure and a non-oxidizing atmosphere.

22. A mobile body device with a positioning function, wherein part or all of a movable section of the mobile body device comprises a sintered powder compact produced according to the method of claim 7.

24. A mobile body device according to claim 22, wherein the mobile body device is a hydrostatic fluid bearing device.

26. A mobile body device according to claim 25, wherein the tabular object is one of a semiconductor wafer and a liquid crystal panel.

27. A mobile body device according to claim 22, wherein said part or all of the movable section has at least one of_ a hollow structure and a rib structure.

28. A mobile body device according to claim 27, wherein said at least one of the hollow structure and the rib structure is formed by arranging molds during slip casting.

29. A mobile body device according to claim 27, wherein said at least one of the hollow structure and the rib structure is formed by joining a plurality of said sintered powder compacts.

30. A mobile body device according to claim 27, wherein said at least one of the hollow structure and the rib structure is formed by soldering the sintered compact.

31. A mobile body device according to claim 27, wherein said at least one of the hollow structure and the rib structure *is* formed by processing the compact before sintering.

32. A hydrostatic fluid bearing device, wherein part or all of a movable section of the device is made of material having a specific rigidity ratio of 100 GPa or more, and part or all of the movable section has at least one of a hollow structure and a rib structure.

33. A protective member for absorbing shock from collision with a missile comprising a sintered powder compact produced according to the method of claim 7.

34. A protective member for absorbing shock from collision with a comprising a sintered powder compact made by slip casting and sintering of a ceramic powder.

35. A protective member for absorbing shock from collision with a missile according to claim 33, wherein the protective member further includes a backup material provided together with the sintered powder compact for absorbing shock from collision with the missile.

36. A protective member for absorbing shock from collision with a missile according to claim 33, further comprising at least one other material provided on opposite sides of the sintered powder compact in a sandwiched structure.

37. A device equipped with the protective member for absorbing shock from collision with a missile according to claim 33 on all or a part of a crust of the device.

38. A device according to claim 37, wherein all or part of the crust equipped with the protective member for absorbing shock from collision with a missile is obliquely provided to an estimated direction of collision with the missile.

39. A device equipped with a protective member with a curved structure for absorbing shock from collision with a missile, comprising a ceramic sintered compact with a curved structure provided on all or part of a crust of the device.

41. A mixture according to claim 15, wherein a main component of the solvent is water.

42. A mixture according to claim 15, wherein a volume fraction of the powder and the high polymer organic substance in the mixture is 1 - 40 parts by volume of the high polymer organic substance to 100 parts by volume of the powder.

43. A production method according to claim 20, comprising a further step of performing HIP treatment on the sintered compact.

44. A device according to claim 39, wherein the protective member is provided obliquely to an estimated direction of collision with the missile.

Abstract

A wet-type compacting method of a ceramic powder using a solvent, wherein the ceramic powder is coated with a high polymer organic substance which is substantially insoluble in the solvent so that homogeneity of a compact is kept, while generating no problem during each process and excellent plasticity and /or strength are exhibited by the compact, and if a sintering process follows a compacting process, sintering characteristics are improved.